pected operation. If the ſame thing ſhould be attempted with this vaſe ſtove, it will be well for the buyer to examine thoroughly ſuch pretended improvements, leſt, being the mere productions of ignorance, they diminiſh or defeat the advantages of the machine, and produce inconvenience and diſappointment.

The method of burning ſmoke, by obliging it to deſcend through hot coals, may be of great uſe in heating the walls of a hot-houſe. In the common way, the horizontal paſſages or flues that are made to go and return in thoſe walls, loſe a great deal of their effect when they come to be foul with ſoot; for a thick blanket-like lining of ſoot prevents much of the hot air from touching and heating the brick work in its paſſage, ſo that more fire muſt be made as the flue grows fouler: But by burning the ſmoke they are kept always clean. The ſame method may alſo be of great advantage to thoſe buſineſſes in which large coppers or caldrons are to be heated.

Written at Sea, 1785.

N° VII.

A Theory of Lightening and Thunder Storms, *by* ANDREW OLIVER, *Eſq. of Salem in the State of Maſſachuſetts.*

Read January, 1774.

IT has been generally, and, conſidering the phenomena themſelves, very naturally ſuppoſed, that the electric charges which are exhibited in repeated flaſhes of lightening during a thunder ſtorm, are previouſly accumulated in the vapors which conſtitute the cloud; and that theſe vapors, when by any means they become either over-charged with electric matter, or are deprived of their natural

natural quantities of it*, difcharge their furplufage to, or receive the neceffary fupplies from, either the earth or the neighbouring clouds, in fucceffive explofions, till an equilibrium is reftored between them. But I fhall endeavour in the following pages to prove, that thefe charges refide, not in the cloud or vapors of which it confifts, but in the air which fuftains them; and that, previous to the formation of the cloud, or even the afcent of the vapors of which it is formed. But, in order to convey my ideas upon this fubject with perfpicuity, I find it neceffary to introduce them with a quotation from doctor *Franklin*'s letters on electricity, in which the doctor compares water, whether in its natural ftate, or rarefied into vapors, to a fponge; and the electric fluid, in connection with it, to water applied to the fponge.

"When a fponge (fays he) is fomewhat condenfed by "being fqueezed between the fingers, it will not receive "and retain fo much water as when it is in its more loofe "and open ftate. If more fqueezed and condenfed, fome "of the water will come out of its inner parts, and flow "on the furface. If the preffure of the fingers be intire-"ly removed, the fponge will not only refume what was "lately forced out, but attract an additional quantity. As "the fponge in its rarer ftate will *naturally* attract and "abforb *more* water; and in its denfer ftate will *naturally* "attract and abforb *lefs* water; we may call the quantity "it abforbs in either ftate, its *natural quantity*, the ftate "being confidered."

The doctor then fuppofes, "that what the fponge is to "water, the fame is water to the electric fluid;—that "when a portion of water is in its common denfe ftate, "it can hold no more electric fluid than it has; if any be "added it fpreads upon the furface." He adds, "when "the fame portion of water is rarefied into vapor and forms

* A body is faid to be electrically charged, whenever it has either *more* or *lefs* than its natural quantity of electric matter.

" a cloud, it is then capable of receiving and abſorbing a " much greater quantity, as there is room for each parti- " cle to have an electric atmoſphere. Thus water in its " rarefied ſtate, or in the form of a cloud, will be in a " negative ſtate of electricity; it will have leſs than its " *natural quantity*, that is, leſs than it is naturally capable " of attracting and abſorbing in that ſtate*."

The foregoing paſſages I have copied *verbatim* from that celebrated electrician, as I purpoſe in the courſe of this eſſay to avail myſelf of his idea of the ſponge, in order to illuſtrate a different theory of thunder clouds, which I now beg leave, though with diffidence of my own judgment, and with all due deference to that of ſo great a man, to ſubſtitute in the room of the foregoing; which I muſt confeſs at firſt ſight carries great appearance of probability with it, and is highly corroborated by the curious and beautiful experiment the doctor made with the ſilver cann, braſs chain, and lock of cotton†.

But in reading doctor *Prieſtley*'s hiſtory of electricity, ſome thoughts of ſignior *Beccaria* occurred, which ſatisfied me that this hypotheſis, however ingenious and plauſible, was inſufficient for the purpoſe of accounting for the riſe and phenomena of thunder ſtorms, the frequent extent and violence of which ſeem to require a more general cauſe than that hinted above, to ſupply them with ſufficient quantities of electric matter.

" Conſidering the vaſt quantity of electric fire that ap- " pears in the moſt ſimple thunder ſtorms (ſays doctor " Prieſtly‡) ſignior *Beccaria* thinks it impoſſible that any " cloud, or number of clouds, ſhould ever contain it all, " ſo as either to diſcharge or receive it. Beſides, during " the progreſs and increaſe of the ſtorm, though the light- " ening frequently ſtruck to the earth, the ſame clouds " were

* Franklin's Letters, page 119.
† Page 121.
‡ Prieſtley's Hiſtory of Electricity, page 325.

" were the next moment ready to make a ſtill greater diſ-
" charge, and his apparatus continued to be as much af-
" fected as ever. The clouds muſt conſequently have *re-*
" *ceived* at one place the moment that a *diſcharge* was
" made from them in another."

Signior *Beccaria* accounts for this vaſt exhibition of electric fire from a thunder cloud, by ſuppoſing that ſome parts of the earth may become more highly charged with the electric fluid than others, and that great quantities of it do ſometimes ruſh out of particular parts, and riſe through the air into the higher regions of the atmoſphere; other parts of the earth becoming caſually deſtitute of their natural quantity of the fluid at the ſame time, and ready to receive it: That a chain of clouds nearly contiguous, or a ſingle cloud extending from one of theſe regions to another, in an oppoſite ſtate, might ſerve as a conductor or conductors to reſtore the electric equilibrium between them, which would equally cauſe thunder and lightening in both regions, and throughout the intermediate clouds*. Here doctor *Prieſtley* juſtly obſerves, that " the greateſt difficul-
" ty attending this theory of the origin of thunder ſtorms
" relates to the *collection* and *inſulation* of electric matter
" within the body of the earth." With regard to the *collection*, the doctor obſerves that his author " has nothing
" particularly to ſay:" Nor indeed without a previous *inſulation* of thoſe parts of the earth which may be concerned in the production of the phenomena, can any ſuch *collection* take place. Now if we conſider that in order to have two regions of the earth thus inſulated, and of ſufficient dimenſions, one to ſupply, and the other to receive the quantities of electric fire diſcharged during one thunder ſtorm of any extent and continuance, the parts inſulated muſt be not ſuperficial regions, but muſt reach to a conſiderable depth; and we muſt ſuppoſe, with doctor Prieſtley, " that the electric matter which forms and ani-
" mates the thunder cloud, iſſues from places far below
" the

* Ibid.

" the ſurface of the earth, and that it buries itſelf there*." But, with deference to the judgment of that unwearied friend to ſcience, I apprehend that ſuch an inſulation is hardly conſiſtent with that diſtribution of conductors, eſpecially of water, which provident nature has made through all parts of our globe; the higheſt mountains being furniſhed with *internal* ſprings and fountains, and watered *externally* by rivulets, which derive their origin from condenſing miſts or melting ſnows upon their ſummits: While the ſurface of the earth in general, not excepting the moſt ſandy deſerts, affords ſupplies of water to thoſe who will be at the pains of digging for it. If then the vapors which conſtitute the cloud are, of themſelves, incapable of furniſhing ſuch quantities of electric matter as are neceſſary for the repeated diſcharges in a ſevere thunder ſtorm, as ſignior *Beccaria* thinks they are, and as ſeems to me indubitable; and if the inſulations of large portions of the ſurface or exterior parts of the earth, which are abſolutely neceſſary to ſupport *Beccaria*'s hypotheſis, cannot take place; which, how they can in our terraqueous maſs, is difficult to conceive, conſiſtently with the *hitherto* diſcovered properties of the electric fluid: We muſt ſeek for ſome other ſubſtance in nature which may be capable of affording thoſe reiterated ſupplies, of that powerful element which are uſually exhibited in a thunder ſtorm. This I preſume, we ſhall find in the atmoſphere over our heads; not in the *vapors* which float therein, but in the *air* itſelf which ſuſtains them.

Air is by electricians juſtly claſſed with *electric* ſubſtances, as it poſſeſſes the ſame general properties in common with others of that denomination, particular inſtances of which may occur in the following pages; wherein I ſhall endeavour to prove,

I. That the *electric capacity* of air is leſſened by condenſation.

II. That *this* capacity is increaſed by heat.

Premiſing

* Prieſtley, page 335.

Premiſing that by *air* I here intend *that* fluid in its common compreſſed ſtate with us near the ſurface of the earth; and by its *electric capacity*, that ſtate of it which diſpoſes it, under any circumſtances whatever, " to attract, abſorb and retain," what doctor *Franklin* calls its *natural quantity*, or the quantity which is *natural* to it in that ſtate.

I. I ſhall endeavour to prove that the *electric capacity* of air is leſſened by condenſation.

That a change of denſity in air produces alſo a change in its electric capacity (as above defined), follows from ſome experiments of monſieur de *Faye* and doctor *Prieſtley*, the former of whom found, upon repeated trials, that no electricity could be excited by the friction of a glaſs tube in which the air was condenſed*. The doctor, repeating the experiments with ſome variation, found, that when one additional atmoſphere was forced into the tube, the electricity excited by rubbing it was ſcarcely diſcernable. Now, though the effect was a ſuſpenſion of the operation of the excited tube *without*, the cauſe was evidently the condenſed ſtate of the air *within;* which may be accounted for if we conſider, that although it is certain from many experiments that glaſs is abſolutely impermeable to the electric fluid, inſomuch that it cannot force its way through a pane of glaſs, or the ſides of a phial, without breaking the glaſs, as was the caſe in thoſe ſpontaneous diſcharges of ſeveral of the jars in the electrical battery mentioned by doctor *Prieſtley*†; yet it is as certain, that this impermeability of the glaſs to the fluid itſelf, is no obſtruction to the operation of that repellent power upon which the viſible effects of this element ſeem principally to depend; which power undeniably acts from one ſide of the glaſs, through the very ſubſtance of it, upon the ſame fluid on the other ſide, provided there be any other ſubſtance on that ſide capable of receiving it when thus repelled.

This is the caſe in the *Leyden* experiment in every form in which it can be made; the charge given to one ſide of the

* Page 50. † Page 489.

the glaſs, repelling and throwing off an equal quantity of the electric fluid from the oppoſite ſurface, through the non-electric coating in contact with it; nor can any charge be given to either ſide without a proportional diſcharge from the other. In like manner, when an uncoated tube is excited by friction, a quantity of the fluid, equal to that which is excited and condenſed upon the outer ſurface, is thrown out from the inner, provided there is any ſubſtance within in a capacity to receive and abſorb it, without which no excitation can take place. "A glaſs tube, "out of which the air is exhauſted, diſcovers no ſigns of "electricity outwards*," there being no ſubſtance within capable of receiving and abſorbing the fluid from the inner ſurface, which though repelled from it inwards during the operation, yet returns to it again inſtantly upon a ceſſation of the action of the rubber without. But upon a readmiſſion of air the excitation is eaſy, and is attended with the uſual effects. Air then, which is the only ſubſtance admitted (excepting perhaps a few ſtraggling vapors which float in it) receives and abſorbs a ſufficient quantity of the electric fluid from the inner ſurface to permit an excitation of the tube which contains it. But as we have ſeen that air, when condenſed within, prevents the viſible effects of an excitation, equally with a total vacuity, we may adopt the idea of doctor *Franklin*, *mutatis mutandis*, and conlcude that "what the ſponge is to water "the ſame is *air* to the electric fluid:" At leaſt that this capacity of air if leſſened by condenſation in a manner, not indeed perfectly ſimilar, but, ſomewhat analogous to that in which the capacity of a ſponge to receive and retain water is leſſened by compreſſion. Agreeably to which idea, the condenſed air within the tube, having its electric capacity filled and even crowded with the electric matter, will receive none from the inner ſurface, which, on the contrary, is thereby prevented from being forced out of it, without which

* Prieſtley's hiſtory of electricity, page 550.

which none can be forced into or condenfed upon the outer furface, fo as to exhibit any figns of electricity; as obferved before,

II. I fhall endeavour to prove that the electric capacity of air is increafed by heat.

This alfo appears probable, at leaft, from the above cited experiments of doctor *Prieftley;* for after the air in his tube had had this capacity fo far diminifhed by condenfation as not to permit an excitation without, that capacity, together with the confequent excitability of the tube, was reftored by the action of heat upon the included air. "Re-
" peating my attempts (fays he) to excite the tube above
" mentioned, I found that, after very hard rubbing, it be-
" gan to act a little, and that its virtue increafed with the
" labour. Thinking it might be the warmth which pro-
" duced this effect, I held the tube to the fire and found
" that when it was pretty hot, it would act almoft as well
" as when it contained no more than its ufual quantity
" of air*."

In page 553, doctor *Prieftley* tells us that fome of his electrical friends were of opinion, " that the reafon why
" a tube with condenfed air in it cannot be excited is, that
" the denfe air within prevents the electric fluid from be-
" ing forced out of the infide of the tube, without which
" none can be forced into the outfide; and that heating
" the tube makes the air within lefs electrical." That is, as I conceive their meaning, puts it in a capacity to receive and abforb more of the electric fluid than it could otherwife do in that condenfed ftate. The doctor indeed queries by way of objection to the foregoing folution,—
" How upon this principle can a folid ftick of glafs be ex-
" cited?" To which I would anfwer, that poffibly, when a folid ftick of glafs is excited, as much of the electric fluid may be drawn out of one fide of it as is thrown into, or condenfed upon the other; if fo, although it may fhew equal figns of electricity on both fides, yet one fide will be in a

 pofitive

* Page 551.

positive, the other in a negative ſtate; when it will exactly reſemble the curious ſtone called the *tourmalin*, by ſome *lapis electricus*, which doctor *Prieſtley* ſays * "has "always, *at the ſame time*, a poſitive and a negative elec-"tricity; one of its ſides being in one ſtate, and the other "in the oppoſite;" which does not depend upon the external form "of the ſtone." But the truth of this ſolution muſt be determined by future experiments.

That the electrical ſtate of the air is liable to be affected by heat, is further evident from a courſe of experiments which were made by the abbé *Mazeas*, with an apparatus that was conſtructed ſolely with a view of determining the electricity of the atmoſphere, anno 1753 †. With this apparatus the abbé obſerved, that from the 17th of June, when he began his experiments, the electricity of the air was ſenſibly felt every day, *from ſun riſe till ſeven or eight o'clock in the evening*, when the weather was *dry*; but that in the drieſt *nights* of that ſummer he could diſcover no ſigns of electricity in the air, nor till the morning, when the ſun began to appear above the horizon, and that "they vaniſhed again in the evening, about half an "hour after ſun ſet;" and further, "that the *ſtrongeſt* "common electricity of the atmoſphere, during the ſum-"mer, was perceived in the month of *July* on a *very dry* "day, the heavens being very clear, and the ſun *extreme-"ly hot*."

Now, as this electricity of the air was ſenſible only during *day light*, no electricity being diſcoverable therein even in the *drieſt nights*, and as the air exhibited the *ſtrongeſt* ſigns of electricity when the ſun ſhone *extremely hot*; is not the concluſion unavoidable, that heat ſomehow affects the electric capacity of air, either enlarging it, and thereby diſpoſing the air to attract, receive and abſorb greater quantities of electric matter than it is capable of abſorbing in its natural ſtate; or ſuperadding to its *natural quantity* more than it can abſorb, and thereby diſpoſing it to throw off

* Page 299. † Page 342.

off the redundancy upon any objects which may be in a situation to receive it? One or the other seems necessarily to follow, but the former is most agreeable to doctor *Priestley*'s experiment of the condensed air in the tube above mentioned, and is perfectly consonant with the observations of doctor *Franklin*, Mr. *Kinnersley* and others, that thunder clouds are generally in the *negative* state of electricity*. But more upon this head hereafter. I would however observe here, that many, and perhaps all other electric substances, even the most firm and solid, as well as air, are liable to have their electric capacities thus diversified by heat, more particularly the tourmalin above mentioned. But as, in treating of the properties of this stone, doctor *Priestley* has thought it deserving of a distinct section in his electric history, to that I shall refer the reader for a particular account of them †; wherein he will find a discovery made by Messrs *Canton* and *Wilson*, that these properties are not peculiar to the tourmalin, but that many gems have a natural disposition to afford the same appearances; from whence we may conclude as above, by analogy, that all electric substances are, more or less, affected in like manner, by the same cause. But to return to the subject.

If from the foregoing considerations the reader should be satisfied, that the *electric capacity* of air, in its condensed state in the lower regions of the atmosphere, is liable to be diminished by a further condensation, and that, *cæteris paribus*, it is increased by heat *et vice versa*; the solution of the phenomena of thunder and lightening, to his satisfaction, upon electrical principles, will perhaps be no difficult task.

For let us conceive a region of the atmosphere, extending over a large tract of country, to be rarefied and heat-

* Epitome of Phil. Transf. Gent. Mag. Sept. 1773, page 447. Mr. Henley thinks cold electrifies the atmosphere positively, and thence conjectures that heat electrifies it negatively. His conclusions are founded upon a course of experiments.

† Page 297.

ed during a hot ſummer's day, not only by the paſſage of the ſun's direct rays through it, and by the reflection of thoſe rays from the ſurface of the earth into it; but chiefly, by the communication of the heat acquired by that ſurface to it: The *electric capacity* of that region of air would be increaſed, both on account of the heat it undergoes, and of the rarefaction conſequent upon that heat: It will then have leſs than its *natural quantity*, or the quantity it is *naturally* diſpoſed to receive and abſorb in that ſtate; it will conſequently be, in the language of electricians, *negatively* electriſed, or in a craving ſtate, requiring and forcing ſupplies from all ſubſtances capable of affording them, provided it be itſelf in a condition to receive them. But, however craving, it cannot receive thoſe ſupplies from the neighbouring regions of the atmoſphere, while thoſe regions ſeverally remain in the ſtate of pure air, even ſuppoſing the latter to poſſeſs more than their *natural quantities*, and thereby as much diſpoſed to impart, as the former is to receive them, without the intervention of non-electric conductors; and that, owing to the impermeability of air, as ſuch, to the electric fluid. This I ſhall endeavour, 1. To illuſtrate by experiments made with glaſs. 2. To prove by experiments made upon air itſelf.

1. If a pane of glaſs be coated on both ſides, by the application of plates of tin to them, the glaſs may be charged in the ſame manner as the *Leyden* phial; when, after the removal of the plates, no diſcharge having previouſly taken place, both ſides of the glaſs will remain charged, one poſitively, the other negatively; the former having more than its *natural quantity*, the latter being proportionably deficient, and in a craving ſtate. Theſe ſtates both ſurfaces will obſtinately maintain for a long time: Nor do I know of any method of reſtoring the electric equilibrium between them, but, either to immerſe the pane in water or ſome other non-electric fluid, which will do it inſtantly, and ſilently; or to reapply the metalline coatings to both ſides

ſides as they were placed at firſt, with a good conductor introduced between them, which will anſwer the ſame purpoſe, and be attended with an exploſion, or ſmart ſpark and ſnap; or laſtly, to place it in a ſituation where it may be expoſed to air replete with moiſt vapors, where, after ſome time, the vapors will, by condenſing upon each ſide, furniſh it with a moiſture equivalent to a non-electric coating, while the vapors which remain in the ſurrounding air will, by continually impinging upon and receding from the two ſurfaces, at length reſtore both to their natural ſtate.

It is evident from the foregoing experiment, *Firſt*, That the charges reſide in the glaſs itſelf, as they remain after the coatings are removed. *Secondly*, That the oppoſite ſides have a very ſtrong propenſity, one to give, the other to receive the fluid, and thereby to reſtore the electric equilibrium between themſelves; which is done with violence, as obſerved above, when they are put in a condition of doing it by the reapplication of the metalline coatings, with a conductor between them, and *Laſtly*, That notwithſtanding the violent propenſity in the ſides of the glaſs, to reſtore themſelves and each other to their natural electric ſtates, and the ſmall diſtance between them, they can never effect it, without the intervention of non-electric conductors.

2. I ſhall now ſhew by other experiments, that different regions or ſtrata of air *may* become charged, both poſitively and negatively, in the ſame manner as the ſides of the pane of glaſs were in the foregoing; and that the effects of ſuch charges are preciſely the ſame.

Meſſrs *Wilkie* and *Æpinus* at *Berlin*, having the hint naturally ſuggeſted to them by a previous courſe of experiments, endeavoured to give the electrical ſhock by means of *air*, in the ſame manner in which it may be given by *glaſs*; "in which after making ſeveral attempts (ſays doc- "tor Prieſtley*) they at length ſucceeded, by ſuſpending "large

* Page 242.

" large boards of wood covered with tin, with the flat ſides " towards one another, and at ſome inches aſunder. For " they found, that upon electrifying one of the boards " poſitively, the other was always negative. But the diſ- " covery was made complete and indiſputable by a perſon's " touching one of the plates with one hand, and bringing " his other hand to the other plate; for he then received " a ſhock through his body exactly like that of the *Ley- " den* experiment. With this plate of air, as we may call " it, they made a variety of experiments. The two me- " tal plates, being in oppoſite ſtates, ſtrongly attracted one " another, and would have ruſhed together if they had " not been kept aſunder by the ſtrings. Sometimes the " electricity of both would be diſcharged by a ſtrong ſpark " between them, as when a pane of glaſs burſts with too " great a charge. A finger put between them promoted " the diſcharge, and felt the ſhock. If an eminence was " made on either of the plates the ſelf-diſcharge would al- " ways be made through it, and a pointed body fixed up- " on either of them prevented their being charged at all."

To the foregoing relation of the experiments themſelves, I ſhall ſubjoin the concluſions drawn from them by the curious electricians who made them, in the words of doctor *Prieſtley*, viz. " The ſtate of theſe two plates, they " (*Wilkie* and *Æpinus*) " excellently obſerve, juſtly repreſents the " ſtate of the clouds and the earth" (and perhaps of different clouds at various heights one over another) " dur- " ing a thunder ſtorm; the clouds being always in one " ſtate, and the earth in the oppoſite; while the body of " air between them anſwers the ſame purpoſe as the ſmall " plate of air between the boards, or the plate of glaſs be- " tween the two metal coatings in the *Leyden* experiment. " The phenomenon of lightening is the burſting of the " plate of air by a ſpontaneous diſcharge, which is always " made through eminencies, and the bodies through which " the diſcharge is made are violently ſhocked."

As

As in the former experiment made with the pane of glaſs, the charges, both poſitive and negative, reſide in the glaſs itſelf, and not in the coatings, thoſe remaining after theſe are removed; ſo in the latter, which is completely analogous to it, the charges are accumulated and reſide in the air ſituated between the boards, and not in their tin linings, which ſerve only as conductors, to diſtribute the fluid equally over, or to convey it equally from, the whole ſurface of air which is limited by, and in contact with them, on either ſide; whereby the whole of each ſurface may be equally charged at the ſame time, or diſcharged by the ſame exploſion.

If two or more regions of the atmoſphere, when free from vapors, become thus differently electrical in their ſtate and capacities, which, that they may, from the heat and conſequent rarefaction in a ſummer's day, we have already ſeen, and perhaps from a variety of other cauſes to us unknown; and if from the contrary currents of air which frequently take place at different heights, they ſhould perchance become ſituated one over or adjacent to another, like ſtrata of minerals within the bowels of the earth; what the metalline coating is to the pane of glaſs, or the tinned boards to the plate of air in the laſt experiment, the ſame would clouds, formed and floating therein, be to theſe regions of air; the electric equilibrium between which might be reſtored through their intervention, either by ſpontaneous diſcharges through the pure air between them in ſevere flaſhes of lightening or through the falling drops of rain, which in their ſucceſſive deſcent form a chain of natural conductors between one region of the air and another, and betwixt each of them and the earth; the paſſage of the electric fluid through which would alſo be attended with lightening and thunder, but not ſo ſevere as when the diſcharge is made through the pure air; the moſt fatal lightening uſually preceding the fall of the rain.

It

It is not uncommon, during the rife and progrefs of a thunder ftorm, to fee different fets of clouds, at various heights in the atmofphere, moving promifcuoufly in all directions, as though they were impelled hither and thither by contending winds; when probably the whole phenomenon arifes from the different electrical ftates of the regions of the air in which they float; as they approach one or other of which, they are attracted or repelled, and move accordingly, communicating, receiving, or tranfmitting the electric fluid, to or from them refpectively, as they may be either deficient of their natural quantity, or poffefs a redundancy of this fluid. And as in the experiment of Meffrs *Wilkie* and *Æpinus* mentioned above, the two tin plates with the boards they covered, would have rufhed together had they not been kept afunder by the ftrings, fo thefe clouds floating freely in air, and being at liberty to act upon every impulfe, gradually coalefce, reftoring the electric equilibrium to the neighbouring atmofphere by repeated difcharges as they unite*; till at length they form one denfe mafs of humid vapors, which precipitating in a heavy fhower of rain, refrefh the thirfty foil, leaving the atmofphere above in a homogenous electric ftate, calm and ferene.

How thefe clouds are generated, formed, and adapted to thofe grand purpofes in the œconomy of nature, is next to be confidered: In profecution of which inquiries I fhall fubmit the following obfervations to the candor of the reader.

Whatever the immediate caufe of evaporation may be, it is certain that the fuperficial moifture of all bodies is perpetually exhaling in vapors, which afcend into the higher regions of the atmofphere, where they gather and are formed into clouds, and at length recondenfe, defcending

* It is certain that in moft thunder ftorms the flafhes of lightening are chiefly difcharged from cloud to cloud, very few, and frequently none at all taking place between the cloud and the earth.

ing in dew, miſt or rain upon the ſurface of the earth from whence they ſprang.

Theſe vapors are either detached in ſtreams from the humid ground by the influence of the ſun, or thrown off by the perſpirations of thoſe infinite multitudes of animals and plants which cover the face of the earth*, or ſupplied by evaporation, from the ocean, or other grand collections of water.

Ignorant as we are of the nature of theſe operations, and of the manner in which they are performed, it is natural to ſuppoſe, that the vapors themſelves aſcend in the ſame electric ſtate, whether poſitive, neutral or negative, with the ſubſtances from which they ariſe. Accordingly ſignior *Beccaria*, in making ſome of his experiments, obſerved, that "ſteam riſing from an electrified eolipile diffuſes it- "ſelf with the ſame uniformity with which thunder clouds "ſpread themſelves and ſwell into arches, extending itſelf "towards any conducting ſubſtance†." This ſtream then was electrified as well as the eolipile from whence it proceeded. The ſea muſt neceſſarily be ſuppoſed, in common with the whole terraqueous maſs, to contain juſt its natural quantity of the electric fluid, and no more: We may therefore conclude that both the vapors which ariſe immediately from it, and the air which ſuſtains them, and from its ſituation enjoys a more equable temperature, than that over the land, are in the ſame electrical ſtate with the ſea itſelf, containing neither *more* nor *leſs* than their *natural quantity*.

Conſidering the vaſt extent of the ocean, and the comparatively ſmall degree of moiſture of which the dry land is ſuſceptible, we may conclude, that a very ſmall proportion of the clouds which are formed in the atmoſphere are exhaled from the latter, and that the ocean is the grand ſource from whence they principally derive their origin.

M Our

* See *Hales's* vegetable ſtatics, and Chambers's *cycloped*, under the word, Perſpiration.

† Prieſtley's Hiſtory, page 327.

Our ſenſes accordingly convince us that the ſea-air is always replete with moiſt vapors, even when its natural tranſparency is not in the leaſt interrupted by them. Hence in a hot ſummer's day, when the wind ſuddenly ſhifts from weſt to eaſt, we immediately perceive a chill from the ſea-breeze; and ſometimes long before the thermometer indicates a change in the temperature of the atmoſphere. Theſe vapors, when they firſt ariſe from the ſea, are generally ſo nearly of the ſame denſity with the ſurrounding and contiguous air, that the rays of light in paſſing through them, undergo no ſenſible change in their refraction; they are therefore at firſt generally inviſible, but when the weather is extreamly cold, and the air of conſequence uncommonly denſe, they are always viſible, and appear like a ſteam ariſing from boiling water*. Not that vapors aſcend moſt copiouſly in the coldeſt ſeaſons, which ſeems contrary both to reaſon and experience; but that the different denſities of the air next the ſurface of the water, and of the vapors which aſcend in it, render the latter viſible, by the irregular refractions of the rays of light in paſſing through them. For the ſame reaſon our breath is viſible in the winter, but not in warm weather.

Let us now ſuppoſe the atmoſphere, on a ſummer's morning, to be all around in a homogenous ſtate, as indicated by a cloudleſs ſky and a dead calm. As the ſun riſes on the eaſtern coaſts of America, and warms and rarefies the atmoſphere eaſtward, the rarefied air naturally aſcends, and a current of air as naturally flows thither from the oppoſite quarter, which is but juſt emerging from the cool ſhades of night, to ſupply its place. The conſequence of which is a light weſterly breeze. As the ſun aſcends higher, the air over the land becomes heated and rarefied, both by the paſſage of the ſun's direct and reflected rays through it, and by the reverberation of the heat acquired from

* This is always the appearance in a clear, ſtill morning, when the mercury in Farenheit's thermometer is at 0, or below it.

from them by the ſurface of the earth; till at length that whole region of the atmoſphere has its electrical capacity enlarged, thereby becoming negatively electriſed, or in a craving ſtate, as obſerved before. On the contrary the ſun's rays which fall upon the ſurface of the ſea, eſpecially when ruffled by wind, chiefly enter that tranſparent medium, in which they are refracted and irrecoverably abſorbed; very few, comparatively, being reflected; whence very little heat can be reverberated from that element to warm the incumbent air, which is ſenſibly affected only by the paſſage of the ſun's direct rays through it, unleſs the weather be calm and the ſurface very ſmooth*. Beſides, it is colder at ſea than aſhore in the ſummer ſeaſon, when, and when only thunder ſhowers are frequent, and indeed warmer in the winter, for the following reaſon, viz. as the ſea is every moment changing its ſurface, neither heat nor cold can affect it ſo ſoon as they do the ſurface of the earth, which continues the ſame.

The air over the land, when thoroughly heated and rarefied, naturally aſcends into the higher regions, while the denſer air from the ſea neceſſarily flows in and takes its place. Hence, probably, the eaſterly winds which uſually ſpring up near the middle of the day, after a ſultry morning.

This body of warm air aſcends till it arrives at that region of the atmoſphere in which thunder clouds are formed; while the vapors which are wafted to the continent by the eaſtern current, being attracted by this now ſuperior air which demands a ſupply of the electric fluid, continually

* In a perfect calm the ſurface of the ſea acts like a mirror upon the ſun's rays, ſtrongly reverberating them back into the atmoſphere, *when* the heat is as ſenſible upon water as upon the dry land. But whenever that ſurface becomes agitated and broken by the force of wind acting upon it, thoſe rays, by perpetually impinging upon an infinite variety of new formed, fluctuating ſurfaces undergo innumerable refractions, in all directions, whereby they are abſorbed and loſt within the fluid maſs in ſome proportion to the violence of the agitation. Accordingly when the weather is ſerene and calm, the ſurface like a looking-glaſs reflects the phenomena of the ſky over head; upon the firſt ſpringing up of a breeze it changes to a light blue, which deepens to a fine ſky-blue as the wind riſes, to a deeper ſea-green in a briſk gale, and to a ſullen blackneſs in a ſtorm, excepting where the waves are interſperſed with white heads of foam, which, by contraſt, only render the ſcene more gloomy.

tinually aſcend till they arrive at it, leaving the denſer air, with which they were firſt connected, behind. As theſe vapors move freely through and mix with air, they eaſily inſinuate themſelves between the particles of that fluid, and unite with it, whereby every particle of air which, from the cauſes aforeſaid, is become in any degree deſtitute of the quantity of electric matter which is natural to it in its preſent ſtate, may and will attract and attach to itſelf one or more particles of this vapor, and thereby furniſh itſelf with a non-electric coating, and thus become qualified to receive from any neighbouring object ſuch a ſupply of the electric fluid as its ſtate may demand.

Thus provided, this body of air, together with the vapors which are more or leſs attached to every particle of it, will conſtitute a denſe cloud; and as the air itſelf was before (by ſuppoſition) in a craving or negative ſtate of electricity; and as the vapors are preſumed to have ariſen from the ocean in their natural or neutral ſtate, the whole body of a cloud formed by them will ſtill be in a negative ſtate, and thereby conſtitute a complete thunder cloud; which when formed, if uniform in denſity and contexture, ſhould it be attracted within the *ſtriking diſtance* from any object ſtanding upon the earth, would have its electric equilibrium reſtored at once by a flaſh of lightening darting from the earth: Or ſhould it paſs near another cloud in a different ſtate, the flaſh would reſtore an equilibrium between the two clouds.

That a body of air, either in a poſitive or negative ſtate of electricity, while pure, ſhould be incapable of communicating its ſurpluſage of the electric element to, or receiving ſupplies from the neighbouring regions, though in a contrary ſtate; and that the ſame air, when replete with watery vapors, may be reſtored to an equilibrium throughout its whole extent by an inſtantaneous diſcharge, may yet require ſome further evidence before it be admitted.

But,

But, as the particles both of air and vapor are ſeverally too minute to fall under our notice, I ſhall endeavour to illuſtrate by analogy what cannot be directly demonſtrated by experiment. In order to this, I ſhall firſt give a general deſcription of, and then ſubjoin ſome obſervations upon doctor *Prieſtley*'s electrical battery.

This battery conſiſted of ſixty four cylindrical glaſs jars fixed in a ſquare box; the jars were coated within and without with tin foil, and the floor of the box was covered with the ſame, whereby the outſides of all the jars formed but one continued electrical ſurface. In like manner, by means of ſmall braſs bars extending over the mouths of the jars in their ſeveral ranges, and by wires which connected the ſeveral bars, together with others which deſcended from them, communicating with the inner coating of each jar, their interior ſurfaces were ſo connected as to form, in the ſame ſenſe, but one ſurface. Thus conſtructed, the whole battery is capable of being equally charged in every part at the ſame time, and of being diſcharged throughout by the ſame exploſion.

Here I would obſerve, that if, inſtead of the metalline coatings, the jars were filled with water to the ſame height with them, and were immerſed in the ſame order in a ſquare veſſel of water to an equal depth, the bars and wire remaining as before, the ſucceſs of all the experiments made with them would be the ſame as above. Let then a battery be conſtructed and charged in this form; after which let the bars and wires aforeſaid be removed, and the water contained in the jars be decanted off by glaſs ſyphons, and let the water be drawn off from the veſſel in which they ſtand. It is evident from the experiment of the charged pane of glaſs already mentioned, and other experiments recited in doctor Franklin's letters, that theſe jars will remain *ſeverally* charged, as they were *jointly* before. They may now, when dry, be taken out and handled at pleaſure with ſafety; nor can they be eaſily re-

ſtored

ftored to their natural ftates, but either by immerfing them fingly under water, or by replacing the whole apparatus and filling both the jars, and the box which contains them, with water as at firft, and introducing a metalline conductor betwixt the water without the jars and any one of the wires which connect their infides; then the whole will be inftantly difcharged with an explofion*.

To apply thefe obfervations to the prefent fubject, we may regard every particle of a body of pure†, but incidentally electrified air, in the fame light with one of the jars in the battery aforefaid, which, after having been charged, is deprived of its adventitious coatings: Each particle, like one of thofe jars, will retain the ftate it may happen to be in, fo long as it remains deftitute of a conducting appendage. But when, and by what means foever, a fufficiency of moift vapors fhall become interfperfed amongft thefe particles of air to furnifh them feverally with non-electric coatings, and by the nearnefs or contiguity of thefe vapors to form a communication from one to another throughout the whole, they will then be in the fame connected ftate with the jars in the battery, when complete in every part, and charged; and like thofe jars be the particles ever fo numerous, they will be in a capacity of jointly receiving or communicating the electric fire. And as, by the addition of jars in the conftruction of the battery, the explofion at the difcharge may be increafed indefinitely, fo will the violence of the explofion from a thunder cloud be increafed in proportion to its extent, and to the multitude of aerial particles together with their appendant vapors of which it confifts, and which are fo connected as to be capable of uniting in the fame difcharge. But as a thunder cloud is not ufually formed at once, but by degrees, fmaller clouds generally forming themfelves in

* Thefe experiments I never faw particularly made, but the conclufions neceffarily follow from fome which I have feen, as well as from thofe pointed out above.

† Pure as to the purpofes of electricity, or free from conducting vapors; perhaps pure elementary air is not to be found in our atmofphere.

in ſeparate parties before they join the main body; and as the electrical ſtates of theſe clouds may be very different from each other, from the different electrical ſtates of thoſe parts of the atmoſphere in which they gather; the general equilibrium of the atmoſphere over a country cannot be reſtored by a ſingle diſcharge, but ſucceſſive flaſhes will dart from cloud to cloud, and betwixt theſe and the earth, till at length the whole collected maſs of vapor is ſpent and diſſolved in rain.

Here a common obſervation naturally occurs, viz. that frequently after a flaſh of lightening a ſudden ſhower deſcends in large drops. The mutual attraction between the vapors and the air, when in this electrical ſtate, is ſufficient to ſuſtain the former, notwithſtanding that they are by this attraction greatly condenſed, being as it were forced into a phyſical contact, both with the particles of air, and with each other*. But as ſoon as the air is reſtored to its natural electric ſtate by a flaſh of lightening, this attraction ceaſes, and the vapors precipitate by their own ſpecific gravity in a heavy ſhower.

Long and extenſive calms, in certain latitudes and ſeaſons, take place upon the ocean, during the continuance of which, the heat is ſcarcely tolerable. (See note, page 91.) Where theſe take place the air will naturally undergo the ſame changes, in its denſity and electric capacity, as the air over the land does in the ſummer ſeaſon, and, when ſufficiently

* A gentleman of my acquaintance, who is both intelligent and curious, informed me ſome years ſince, that he was once upon the top of a mountain in Spain, upon which a thunder cloud gathered; that as ſoon as the cloud became inſulated from the mountain it diſcharged a violent tempeſt of thunder and lightening upon the plains below; that he never was ſo thoroughly ſoaked in the moſt violent ſhower as when in the body of this cloud, though without a drop of rain, feeling as if he had been immerſed in a river. This idea is further juſtified by the ſolid appearance of the clouds that riſe in the weſt on a hot ſummer's day, compared with thoſe which float in the atmoſphere at other ſeaſons; which ſhews a manifeſt difference in their denſity and contexture: And when we obſerve attentively the ſeveral parts of a thunder cloud, the diſtinctneſs of their borders and their ſwelling furbeloes; how ſtrongly they reflect the rays of the ſun, thereby exhibiting the moſt vivid lights and deep contraſting ſhades; and on the other hand obſerve the beautiful effects of their refractive power in the intenſe golden ſkirts which adorn the riſing cloud with a ſetting ſun behind it; we muſt neceſſarily conclude, that, although the vapors of which ſuch clouds conſiſt are collected and condenſed in higher regions of the atmoſphere than are thoſe which uſually form clouds at other ſeaſons, yet their denſity and ſpecific gravity is much greater; and they derive their ſupport from the electric principle.

ſufficiently heated and rarefied, will in like manner aſcend, its place being ſupplied by the denſer air from all quarters without the limits of the calm. This heated and conſequently (granting the principles of the preſent theory) electrical air, when raiſed to a certain height in the atmoſphere, may become as well adapted to the formation of a thunder cloud, from the vapors which are perpetually exhaling from the ſea, as the air over the land under the like circumſtances. Wherefore, in ſome latitudes in all ſeaſons, and perhaps in all latitudes in different ſeaſons of the year, thunder ſtorms may as well happen at ſea, even at remote diſtances from land, as aſhore.

I now proceed to conſider an objection which may be raiſed againſt the foregoing theory, which I ſhall firſt ſtate in its full force, and then endeavour to give a ſatisfactory anſwer to it.

Objection. If the electrification of that body of air in which a thunder cloud is formed depends upon the *heat* it has previouſly acquired, whence is it that thunder ſtorms are frequently attended with ſhowers of hail, which hail is ſometimes ſo large as to indicate its deſcent from the coldeſt regions of the atmoſphere?

Anſwer. Sir *Iſaac Newton* aſſerts from experiments of his own, that " the denſity of the air in the atmoſphere of " the earth is as the weight of the whole *incumbent* air." Conſequently the air gradually decreaſes in denſity from the ſurface of the earth to the top of the atmoſphere. The body of air which is ſuppoſed in this *theory* to be qualified by the action of heat upon it, to become a proper *ſubſtratum* for the formation and ſupport of a thunder cloud, is thereby expanded and rarefied, and thence becomes ſpecifically higher than it was before: It therefore aſcends till it arrives at that height in the atmoſphere at which the air is naturally, from its ſituation, of the ſame rarety with itſelf; and there it reſts in equilibrio. This region is extreamly cold at all ſeaſons, as appears from the teſtimonies

of

of travellers who have viſited the tops of very high mountains, even under the line. The greater the heat which this body of air acquires below, the greater degree of rarefaction it undergoes, and the higher, of conſequence, it aſcends in the atmoſphere, where the cold is proportionably more ſevere than is uſual near the ſurface of the earth. But though it was the heat which it acquired below that firſt rarefied and expanded it, it will by no means be proportionably recondenſed by the cold which it meets with in its aſcent; for as the heat which occaſioned its rarefaction decreaſes upon that account, the preſſure of the incumbent atmoſphere upon it decreaſes as it riſes, whereby its denſity may, upon the whole, remain nearly the ſame; if ſo, may we not ſuppoſe its electrical ſtate alſo, previous to the formation of the cloud, to continue nearly the ſame? For ſhould this warm air aſcend all together as in a body, without intermixing with the denſer ſurrounding air through which it riſes, as a bubble of air does in any other fluid, and as *this* air probably would in a calm ſeaſon, the denſer parts of the atmoſphere eaſily giving way to it, till it arrives at that region the denſity of which is equal to its own, where it would be at reſt; ſhould this, I ſay, be the caſe, it would not, even in that cold region, cool ſo ſuddenly as to undergo any immediate change in its electrical ſtate, from the natural coldneſs of the region; neither would it be from condenſation, its denſity remaining nearly the ſame, as obſerved above.

But when the cloud is formed, or rather when a number of clouds are forming in the neighbourhood of each other, and joining their forces preparatory to the tempeſt, a general confuſion takes place in the atmoſphere; various and even contrary currents of air flowing promiſcuouſly hither and thither, as is evident from the viſible irregular motions of detached parts of the clouds. In this general effort of nature to reſtore an equilibrium, ſome of theſe aerial currents will probably introduce air, which having been

till now at a diſtance from the ſcene of action, has ſuffered no material change in its *natural* electric ſtate*; and is on the contrary fraught with all the cold which is natural to the region of the atmoſphere from whence it came. In falling through this adventitious current of air, the drops of rain, precipitating from the body of clouds above, are congealed into ice, and deſcend in hail, which as it falls collects other ſnowy or icy particles round it; a hail-ſtone when it comes to the ground reſembling denſe ſnow with a nucleus or kernel of ſolid ice in the middle.

That the air which this hail-ſtone falls through is colder than the region from whence it deſcends, may be thus proved, viz. If the freezing took place where, and as ſoon as the vapors were firſt ſet at liberty by a flaſh of lightening, it would be impoſſible for them ever to unite into drops, but they muſt deſcend in the fineſt chryſtals, an aſſemblage of which conſtitutes a flake of ſnow; the nucleus, or proper hail-ſtone then muſt have been firſt a fluid drop, and afterwards congealed in its fall through a colder region than that in which it was formed.

It may be further objected, that a thunder cloud, in the eaſtern parts of America, always makes its firſt appearance in the weſt, over the land, its progreſs being *towards* the ſea; which ſeems to contradict the ſuppoſition in the theory, that the vapors of which it conſiſts are chiefly ſupplied *from* the ſea.

To which I anſwer, 1. That a thunder cloud is with us very rarely, indeed ſcarcely ever formed in the weſt, without a ſea-breeze ſpringing up previouſly from the eaſt, 2. That the ſea air, as obſerved before, always abounds with vapors, although from the cauſes already aſſigned, they are uſually, at their firſt riſing, inviſible. 3. That the firſt appearance of a cloud will always be where the vapors are

* This ſuppoſition will be juſtified by conſidering, that ſuch is frequently the ſtate of the atmoſphere, that the thunder clouds which are formed in it are but of ſmall extent; notwithſtanding which, the change in the ſtate of the air occaſioned by them is perceived to the diſtance of many leagues round.

are firſt collected into a body and condenſed, and thereby rendered viſible, which in a thunder cloud will be in the weſt, notwithſtanding the vapors of which it conſiſts may chiefly have ariſen from the ſea. 4. That when a thunder cloud is once formed it will be in a ſtate of attraction with the earth in general, and more eſpecially ſo with all ſubſtances which are natural conductors of the electric fluid, ſuch as the water contained in rivers, bays, arms of the ſea, &c. and by theſe the courſe of a thunder cloud is known to be very ſenſibly affected.

But the ocean is the grand object towards which its courſe will be directed; accordingly the progreſs of the clouds is from the weſtern horizon, eaſtward, be the weather below what it may, not excepting the moſt violent eaſterly ſtorms, which are ſometimes, though but rarely, accompanied with thunder and lightening.

To the foregoing obſervations I would add, 5. That when an extenſive thunder cloud is forming in the atmoſphere by means of the mutual attraction of the condenſing vapors, and the body of electriſed air which ſuſtains and condenſes them, the increaſing denſity of the whole compound maſs of air and vapor will, by degrees, occaſion its redeſcent towards the earth, from the law of gravity; it will alſo be attracted by, and move towards the ocean, upon the principles of electricity; the cloud will then deſcend obliquely, in a diagonal between the directions of theſe two powers; and both, continually acting upon it, will jointly accelerate its motion. Such a cloud, if denſe and large, would end in a perfect tornado, either upon the land or water, as thunder ſhowers frequently do; ſmaller clouds being alſo, uſually, accompanied with guſts or flurries of wind.

I ſhall here add one obſervation more which I have frequently made, and which may tend to confirm the foregoing theory, viz. That as the general courſe of the eaſtern coaſt of north America is from north-eaſt to ſouth-weſt;

the courſe of a thunder cloud is uſually from the north-weſt, with the wind at ſouth-eaſt, perpendicular to the direction of the coaſt, and contrary to each other.

Inland ſeas and great lakes, ſuch as are thoſe in North-America, may anſwer the ſame purpoſes in the interior parts of the country, as the ocean does near the limits of the continent; both by affording the neceſſary ſupplies of vapors for the formation of the clouds, and by their attractive influence upon thoſe clouds when formed.

I now conclude with a few hints, which I ſhall throw into the form of queries.

1. Whatever the primary cauſe of evaporation may be, does not the formation of vapors into diſtinct clouds depend upon the electrical ſtate of the atmoſphere?

2. Were the atmoſphere always uniformly electrical could we have any rain*; in that caſe, if evaporation be performed independent of electricity, ſhould we not be invelloped in everlaſting fogs?

3. Mr. *Canton* ſuppoſes that the *aurora borealis* may be "the flaſhing of electric fire from poſitive towards negative clouds, throughout the upper part of the atmoſphere." But as the air is uſually charged more or leſs with vapors, even when perfectly pellucid; and as the moſt remarkable *auroræ* frequently appear without a cloud in the hemiſphere, may not this phenomenon be rather occaſioned by the "flaſhing of electric fire," from one region or body of air to another in a different ſtate of electricity, through the intervening vapors?

4. May not the reaſon of its uſual appearance in the north and of its flaſhing ſouthward be, that, in every northern latitude, the air to the ſouthward is at all ſeaſons of the year, *cæteris paribus*, more affected by the heat of the ſun than the air northward of the ſame latitude; and does not this occaſion an electrical current to flow from north to ſouth,

* Signior *Beccaria* concludes from experiments, that gentle rains are the effects of a moderate, as thunder ſhowers are of a more plentiful, electricity.

ſouth, ſo often as the above mentioned circumſtances concur, though with ſome interruption from the irregular diſpoſition of the conducting vapors; and may not this occaſion thoſe gleams and ſtreams with which this phenomenon is uſually attended?

N° VIII.

Theory of Water Spouts, by ANDREW OLIVER, *Eſquire, of Salem in the State of Maſſachuſetts.*

IN my laſt I took the liberty to communicate to the Philoſophical Society a Theory of *Lightening* and *Thunder Storms*, which was ſuggeſted to my mind upon the peruſal of doctor *Prieſtley's hiſtory of electricity.* In the inveſtigation of which theory, while I was endeavouring to account for the exhibitions of thoſe phenomena upon the ocean, at great diſtances from the land, ſome thoughts naturally occurred relative to the *water ſpout;* a phenomenon as curious perhaps as any one in nature, and which can rarely take place but at ſea.

WATER SPOUTS have by ſome been ſuppoſed to be merely electrical in their origin; particularly by ſignior *Beccaria,* (*Prieſtley*'s hiſt. of elect. p. 355, 356) who ſeems to have ſupported his hypotheſis by ſome experiments. But as ſeveral ſucceſſive phenomena are neceſſary to conſtitute a complete water ſpout, (ſome of which undoubtedly depend upon the electric principle) if we attend to the moſt authentic deſcriptions of theſe ſpouts, through their various ſtages, from their firſt exhibition to their total diſſipation, we ſhall be obliged to have recourſe to ſome other principle, in order to obtain a complete ſolution. I ſhall therefore, *firſt,* deſcribe theſe phenomena according to the beſt obſervations I have met with; and *then,* endeavour to give